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The Honorable Roscoe G. Bartlett
Chairman
The Honorable Silvestre Reyes
Ranking Member
Subcommittee on Tactical Air and Land Forces
Committee on Armed Services
House of Representatives

Subject: *Cancellation of the Army's Autonomous Navigation System*

The Army intended the Autonomous Navigation System (ANS) to enable ground robotic vehicles to partially drive and navigate themselves and to do so in remote areas with difficult terrain, by integrating sensors, processors, and software. Initially, the Army was developing the system as part of manned and unmanned ground vehicles (UGV) that were part of the Army's Future Combat System (FCS) program. But after the cancellation of various FCS vehicles beginning in 2009, the Army planned to couple ANS with the yet-to-be developed Multi-Mission Unmanned Ground Vehicle (MM-UGV), which among many uses was intended to counter roadside bombs – or improvised explosive devices (IED) – in Iraq and Afghanistan. General Dynamics Robotic Systems (GDRS) was the contractor for ANS.[1]

The Army made considerable effort to develop and validate a requirement for the MM-UGV and ANS; however, both were cancelled in 2011. With the cancellation of these efforts, you expressed interest in the impact on Army future autonomous unmanned ground capabilities. In response, we examined:

- To what extent did the Army demonstrate ANS capabilities prior to cancellation?
- What methods did the Army use to compare ANS to commercially available and other alternatives, particularly in the area of field demonstrations?

[1] Boeing was the prime contractor for the FCS program, with subcontractor GDRS responsible for the ANS portion of the program.

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- To what extent does a validated requirement exist for this capability, and how does it fit in with other UGV initiatives?

To conduct our work, we obtained and analyzed Army and contractor documents and test reports to determine ANS progress prior to cancellation, methodology used in comparing ANS to other alternatives, and validated need for vehicles and autonomous capability. We also interviewed officials from a variety of Army and Department of Defense (DOD) offices as well as GDRS.

We conducted this performance audit from February to August 2012 in accordance with generally accepted government auditing standards. Those standards require that we plan and perform the audit to obtain sufficient, appropriate evidence to provide a reasonable basis for our findings and conclusions based on our audit objectives. We believe that the evidence obtained provides a reasonable basis for our findings and conclusions based on our audit objectives. A more detailed description of our scope and methodology is presented in the enclosure.

Results in Brief

Almost all ANS hardware and most software development were completed prior to its cancellation, according to the Army and GDRS. The software for the most advanced capabilities was not completed, which potentially presented the greatest complexities. GDRS had demonstrated many of ANS's capabilities to some extent, including its capability to avoid obstacles and follow a leading vehicle through varying terrain. ANS had not yet progressed to the independent testing phase, however. In cancelling ANS and MM-UGV, the Army estimated that approximately $2.5 billion in planned funding for fiscal years 2013 to 2017 could be made available for other Army efforts. According to Army officials, the government owns the work completed on ANS to date.

To compare ANS to other alternatives, the Army engaged a team (the Red Team) to perform a functional comparison of the demonstrated capabilities of ANS and six other military and commercial systems. The Red Team, comprised of robotics experts with prior knowledge of the systems, found that ANS did not provide a unique capability relative to the other systems evaluated with respect to basic navigation functionality. However, the Red Team noted that ANS was designed for and had demonstrated capabilities for operating in an off-road environment, unlike some of the other systems. The Red Team, which had previously witnessed demonstrations of some of the systems, did not conduct field evaluations for the study due to time constraints, nor did the team rely on testing data and reports on the different systems.

DOD has not validated a requirement for a UGV with an ANS-like capability using the traditional requirement processes, despite attempts to do so. On the other hand,

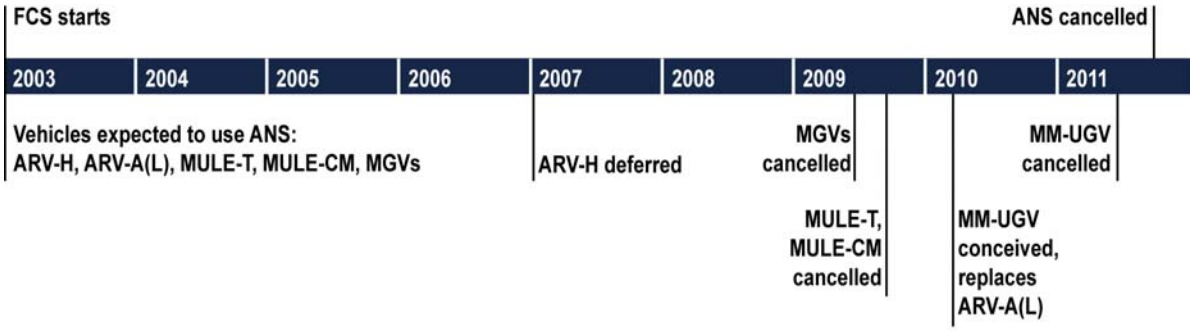
urgent needs statements from battlefield commanders indicate some desire for unmanned ground capabilities—especially in countering IEDs. Several efforts have been underway to address these urgent needs, but nothing has yet resulted in a full scale development program.

Background

Initially, the Army intended for ANS to serve as the autonomous navigation system for as many as 13 manned and unmanned vehicle types as part of the FCS. Since it started in 2003, FCS had been at the center of the Army's efforts to modernize into a lighter, more agile, and more capable combat force. The FCS concept involved replacing existing combat systems with a family of manned and unmanned vehicles and systems linked by an advanced information network. In support of FCS, the Army planned for ANS to provide UGVs with various capabilities, including remote operation, the ability to follow roads, and the ability to follow other vehicles or a walking soldier. Over time, development on FCS vehicles was deferred or cancelled, and the requirements documents supporting the FCS program were discontinued due to shifting priorities in the Army.

Figure 1 shows the timeline of the ANS program as well as the various vehicle options that were considered through the cancellation of the ANS in 2011.

Figure 1: Timeline of ANS from 2003 to 2011



FCS	Future Combat System
ANS	Autonomous Navigation System
ARV-H	Armed Robotic Vehicle – Heavy
ARV-A(L)	Armed Robotic Vehicle – Assault (Light)
MULE-T	Multifunction Utility/Logistics Equipment – Transport
MULE-CM	Multifunction Utility/Logistics Equipment – Countermine
MGVs	Manned Ground Vehicles (9 types)
MM-UGV	Multi-Mission Unmanned Ground Vehicle

Source: GAO analysis of Army data.

Despite cancellation of the FCS vehicles, ANS continued development as a potential add-on package for future vehicles including the MM-UGV. The goal of the MM-UGV was to develop an UGV platform that could accept multiple mission packages, including sensors, weapons, counter-IED, and other mission packages. Several analyses of ANS have been conducted over the years to study its utility, including the Red Team analysis in 2011.[2]

The Army assembled the Red Team in 2011 to provide a top-level, independent look at ANS and provide a recommendation to the Vice Chief of Staff of the Army on whether continued investment was warranted. The Red Team report addressed topics such as whether there were existing requirements for an autonomous navigation capability; if ANS was unique compared to demonstrated basic autonomous navigation capabilities from the military and commercial sectors; and whether the unique qualities of ANS might make it worthy of continued development under the current contract.

Army Made Progress with ANS, but Development Was Incomplete When Cancelled

The Army made considerable progress developing ANS by the time of its cancellation, including completing its Critical Design Review and releasing its technical drawings. The Army and GDRS generally agree that the development of about 90 percent of ANS hardware was complete, as was about 75 percent of the ANS software. GDRS was developing ANS in three planned software phases with each phase building upon the previous phase to increase autonomous capability. Of the three phases, the first was complete, the second mostly completed, and some work had started on the third. However, some of the remaining software work was for the most advanced capabilities—operating at higher speeds and safely following a soldier—which may have been costly and time consuming to complete because of the increasing complexity.

The Army and GDRS had completed initial demonstrations of ANS hardware and software on nine different vehicles.[3] For example, GDRS had conducted multiple demonstrations of ANS's capability to avoid obstacles and follow a vehicle leader or a route through varying terrain at moderate but not the higher, required speeds. To fully demonstrate ANS capabilities, however, would have required its participation in independent operational testing with a fully developed software suite. Operational testing provides independent assessment of a system's capabilities outside of a contractor's or Army's controlled environment by an objective third party. The Army cancelled ANS before these tests could be conducted, since such testing occurs closer to the beginning of production, which ANS had not yet reached.

[2] Autonomous Navigation System Assessment.

[3] All of the ANS demonstrations were on non-FCS vehicles because FCS vehicles were unavailable to GDRS.

Although the Army did not have a separate cost estimate to complete ANS development at the time of cancellation, estimates anticipated that an additional $50 million would be spent for planned development work in fiscal year 2012. Separately, GDRS proposed a reduced scope of work for $35 million in fiscal year 2012 to complete development work that had already been started. The Army did not accept this proposal. According to the Army, cancellation of MM-UGV (and ANS) was expected to make about $2.5 billion in funds available for fiscal years 2013 to 2017 for reinvestment by the Army. In addition, the Army has not yet determined the costs of terminating ANS.

According to Army officials, the Army owns the ANS hardware completed prior to its cancellation. In addition, according to the Army, they have government purpose rights to certain software and hardware technical data, which allows the government to use it for its own purposes.

Functional Comparison Found ANS Not Unique in Basic Autonomous Navigation Compared to Other Alternatives

For the most part, ANS did not provide unique capabilities relative to six other systems for completing basic semi-autonomous navigation tasks, according to the Army's Red Team study done over a 10-day period in 2011. ANS's ability to operate in structured and predictable environments was similar to that of the compared systems. That, coupled with a lack of existing Army requirements, led to the Red Team to conclude that a justification did not exist for continued investment in ANS.

The other six military and commercial systems are described in table 1.

Table 1: ANS-like Systems Evaluated by Army Red Team

System Name	Sponsor	ANS-Like Capabilities
Cargo-UGV	Marine Warfighting Lab	Remote Operation, Vehicle Leader/Follower, Road Following
Ground Unmanned Support Surrogate	Marine Warfighting Lab	Remote Operation, Soldier Leader/Follower
Convoy Active Safety Technologies	Army Tank and Automotive Research, Development, and Engineering Command	Remote Operation, Vehicle Leader/Follower, Road Following
Mobile Autonomous Robotics Technology Initiative	Southwest Research Institute	Remote Operation, Solider and Vehicle Leader/Follower, Road Following
Commercial Auto/Truck	Various	Vehicle Leader/Follower, Road Following
Google Driverless Vehicle	Google	Road Following

Source: GAO presentation of data from Red Team Study report.

The study compared ANS functionality to these systems in terms of three critical autonomy areas: External Sensing, Intelligence and Behaviors, and Modes of Operations and Terrains. In addition, the study included Technical Maturity and Testing and System Cost metrics. The Red Team reviewed and evaluated the systems based on demonstrated capabilities to date, not planned or intended capabilities. Team members were subject matter experts in robotics, had knowledge of the systems being compared, and had previously witnessed numerous evaluations of ANS and the comparative systems. The Red Team did not conduct field evaluations of the systems for the study due to time constraints, nor did they draw upon testing data and reports.

While comparative systems provided similar basic autonomous navigation capabilities, the Red Team also found that ANS had other capabilities. For example, ANS provided a fuller range of capabilities and had undergone more demonstrations and military hardening, such as the ability to operate in a combat environment and protect against electromagnetic interference, which was the most significant overall cost driver. In addition, ANS had been designed and had demonstrated capability for operating in an off-road environment, unlike some of the other efforts. The

commercial systems evaluated had been operated almost exclusively on paved roads and in structured environments.

The study also found that ANS was not out of line with the cost range of the other military and commercial systems evaluated. ANS's anticipated production cost of about $250,000 per system was somewhat less than the Marine Warfighting Lab's Cargo-UGV and Ground Unmanned Support Surrogate, both of which are estimated to cost over $300,000 per system. However, Google's Driverless Vehicle and the Southwest Research Institute's Mobile Autonomous Robotics Technology Initiative, which are expected to cost $150,000 each, would be less expensive than the estimate for ANS. Red Team members noted, however, that five of the systems that were evaluated against ANS used cost estimates based on prototypes, while only the commercial automotive systems and ANS had production cost estimates.

Part of the ANS's higher cost was due to the pursuit of the original FCS requirements—to fit ANS into the broader FCS network. Some of the FCS requirements were as follows:

- Modified sensors to avoid enemy detection;
- More sensors to be able to drive backwards at speeds equal to driving forwards;
- Global Positioning System designed to work in combat environments; and
- Hardened components to protect the system in a combat environment against shock and electromagnetic interference.

GDRS was directed to continue to develop ANS to these original requirements even after FCS was cancelled. Some of these requirements went well beyond the capabilities of comparative systems. However, these requirements and capabilities fell outside of the consideration range of the five metrics that were used to evaluate the systems in the Red Team report.

DOD Did Not Have Validated Requirements for ANS; Other Initiatives in Earlier Stages

Despite several attempts to do so, DOD does not have a validated requirement for a UGV with an ANS-like capability. When development efforts become formal acquisition programs, they are generally based on requirements validated by the Joint Requirements Oversight Council (JROC) or another delegated validation authority. Since the cancellation of FCS, no validated requirements exist for an autonomous UGV. The cancellation of MM-UGV was due, at least in part, to the inability to validate its requirements because of changing user priorities.

The Army is currently leading an effort to complete an Unmanned Initial Capabilities Document for Air, Land, and Sea, which is a prerequisite to obtaining JROC-validated requirements. However, this effort has been underway since November 2009 and the Army is still in the process of resolving comments and the document is still being revised. According to Army officials, it is uncertain when it will be finished. Yet, defining common unmanned capabilities for all of the services is essential. In a March 2010 testimony, we noted that DOD recognizes that to more effectively leverage its acquisition resources, it must achieve greater commonality and efficiency among the military services' various unmanned system acquisition programs.[4] We also noted that DOD stated in its Unmanned System Roadmap there is the potential for an unprecedented level of collaboration to meet capability needs and reduce acquisition costs by requiring greater commonality among the military services' unmanned systems.

An alternative approach to validating requirements through the JROC is the process set up by DOD to rapidly acquire solutions for urgent operational needs.[5] The objective of this process is to validate an urgent need, identify a source of funding, and promptly field a ready solution. Compared with traditional acquisitions, which can take at least several years, rapid acquisitions can be completed within 24 months. Both the Army and DOD, which was supported by the Joint Improvised Explosive Device Defeat Organization, have identified urgent operational needs for a UGV with the capability to counter IEDs. However, when these initiatives were prioritized relative to other needs, it was determined that they were not high enough on the priority list to warrant pursuing due, in part, to the maturity of the counter-IED sensors.

Despite the cancellation of ANS and the lack of a validated requirement, there are several UGV initiatives in the research stage. These include the Squad Mission Support System which recently completed testing in Afghanistan; the Safe Operations of Unmanned Systems for Reconnaissance in Complex Environments which is in testing; and the Supervised Autonomy to Neutralize and Detect IEDs which will be safety tested and then cancelled. We found that all were in the preliminary stages of development but most were not close to achieving the developmental progress of ANS.

[4] GAO, *Defense Acquisitions: DOD Could Achieve Greater Commonality and Efficiencies Among its Unmanned Aircraft Systems,* GAO-10-508T (Washington, D.C.: March 23, 2010)

[5] GAO, *Urgent Warfighter Needs: Opportunities Exist to Expedite Development and Fielding of Joint Capabilities, GAO-12-385 (Washington, D.C.: April 24, 2012).*

Agency Comments

We provided a draft of this report to DOD for review. DOD provided technical comments that were incorporated, as appropriate.

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We are sending copies of this report to appropriate congressional committees and the Secretaries of Defense and the Army. In addition, the report will be available at no charge on the GAO website at http://www.gao.gov. If you or your staff has any questions concerning this report, please contact me at (202) 512-4841 or martinb@gao.gov. Contact points for our Offices of Congressional Relations and Public Affairs may be found on the last page of this report. Key contributors to this report were Bill Graveline, Assistant Director; James Kim; Ioan Ifrim; Bob Swierczek; Alyssa Weir; and Roxanna Sun.

Belva Martin, Director

Acquisition and Sourcing Management

Enclosure

Enclosure

Scope and Methodology

To conduct our work, we obtained and analyzed Army and contractor documents, and test reports to determine ANS progress prior to cancellation, methodology used in comparing ANS to other alternatives, and validated need for vehicles and autonomous capability.

We interviewed officials from the following offices.

- U.S. Army: Tank Automotive and Armaments Command—Tank Automotive Research, Development and Engineering Center; Program Executive Office—Ground Combat Systems; Training and Doctrine Command—Army Capabilities Integration Center; Army G-3/5/7—Operations, Plans and Training; Rapid Equipping Force; Office of the Assistant Secretary of the Army for Acquisition, Logistics, and Technology; and the Army Audit Agency.
- Robotic Systems Joint Program Office; Office of the Undersecretary of Defense for Acquisition, Technology and Logistics, Joint Ground Robotics Enterprise; Marine Corps Warfighting Laboratory; and the Joint Improvised Explosive Device Defeat Organization.

We also interviewed Red Team members at the following offices: U.S. Army Tank Automotive Research, Development and Engineering Center—Ground Vehicle Robotics; Office of the Assistant Secretary of the Army for Acquisition, Logistics and Technology—Research and Technology; and the Office of the Undersecretary of Defense for Acquisition, Technology and Logistics / Office of the Deputy Assistant Secretary of Defense for Strategic and Tactical Systems, Land Warfare and Munitions—Joint Ground Robotics Enterprise.

We also visited and interviewed officials at General Dynamics Robotic Systems.

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